On the Geometric Structure of the Nonlinear Dynamics of Finite Element Models of Elastic Solids and Structures

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The numerical approximation of nonlinear problems in continuum and structural mechanics has had many major advances in the recent past. A complete account of these developments can be found in the monographs by the late Professor Michael A. Crisfield [1,2], including many of his very important contributions to the field. In this respect, we can quote his results in the development of new finite elements and the formulation of converving/dissipative integration algorithms for the integration of nonlinear dynamics of solids and structures, to mention just a few. In this later case, the formulation of numerical approximations that exhibit the required material frame indifference (objectivity) inherent to the physical theory is one of his and co-workers' latest developments of the most interest.

First we plan to present a summary of the results that we obtained in the past in the numerical approximation of the dynamics of solids and structures. The points were the direct interactions with Mike Crisfield and his work became crucial will be especially emphasized. This will include the formulation of energy-momentum conserving numerical algorithms for the nonlinear dynamics of elastic continuum solids (including their contact and impact), nonlinear rods and shells. The added need of a controlled energy dissipation in the high frequency to handle the numerical stiffness in the practical systems of interest will be briefly discussed, identifying in the process the fundamental requirement of preserving the conservation laws of momenta. In fact, these arguments only emphasize the importance of approximating correctly the very rich geometric structure of the underlying Hamiltonian system. Objectivity is only one particular aspect of the invariance of the formulation under the group of rigid body motions in the quasi-static case. Similarly, this invariance leads directly to the conservation laws of momenta and the existence of the associated relative equilibria in the dynamic setting. The complete description of the geometric structure behind the dynamics of a finite element model appears then fundamental. In this way, we will present the above summary in a form outlining this structure. We will discuss how these developments define very interesting new problems. Very recent results in this respect will be presented.

References

1. M.A. Crisfield, *Non-linear Finite Element Analysis of Solids and Structures. Volume 1: Essentials*, John Wiley and Sons, Chichester, 1991.

2. M.A. Crisfield, *Non-linear Finite Element Analysis of Solids and Structures. Volume 2: Advanced Topics*, John Wiley and Sons, Chichester, 1997.